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An Event-Driven Microservice Blueprint for Spring Boot and Apache Kafka: Decomposition, Delivery Semantics, Consistency, and Operations by Construction

Harouna Wendpanga Yann Christian Sankara[1*], Serif Oyindamola Oyesiji[2], Kingsley Chinazaekpere Ndupu[3] & Stanley Nwakamma[4]

[1]*Independent Researcher, Dallas, TX, United States of America.*
[2]*Harrisburg University of Science and Technology, Harrisburg, PA, United States of America.*
[3]*Kennesaw State University, Georgia, United States of America.*
[4]*Independent Researcher, United States of America.*
Corresponding Author Email: christiansankara@gmail.com[*]

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ABSTRACT

Event-driven microservices promise what synchronous service meshes struggle to deliver, loose coupling, independent evolution, natural audit trails, and resilience to partial failure, yet teams adopting the style discover that the promise is conditional on dozens of design decisions the pattern literature names but rarely assembles: how domains map to services and services to topics, how events are typed and evolved, where ordering is guaranteed and where it is surrendered, how state changes and event publication are made atomic, how long-running processes coordinate without distributed transactions, and how the whole is observed, tested, and operated. This paper proposes an opinionated, end-to-end blueprint for event-driven microservices on a concrete and widely deployed stack, Spring Boot services over an Apache Kafka backbone, in which those decisions are made once, coherently, and with stated rationale. The blueprint specifies a decomposition discipline grounded in domain-driven bounded contexts with events as the published language between them; a backbone design covering topic taxonomy, partitioning by aggregate identity, schema management with explicit compatibility rules, and delivery semantics declared per event class; a consistency layer built on the transactional outbox for atomic state-and-event writes, idempotent consumers for effective exactly-once processing, and saga orchestration for multi-service workflows with specified compensation; and an operational plane covering containerized deployment, health and readiness semantics, distributed tracing with correlation propagated through events, consumer-lag-centered monitoring, and resilience patterns at every boundary. An evaluation plan assesses the blueprint through a reference implementation: conformance tests over the consistency guarantees, chaos experiments against the resilience claims, load characterization of the backbone configuration, and comparative implementation studies against an unguided baseline. Applications, migration pathways from monoliths, and limitations are analyzed.

Keywords: Event-Driven Architecture; Microservices; Spring Boot; Apache Kafka; Domain-Driven Design; Bounded Contexts; Event Sourcing; Transactional Outbox Pattern; Saga Orchestration; Distributed Systems; Fault Tolerance; Distributed Tracing.

1. Introduction

Microservices reorganized service-oriented ideas around independently deployable, independently scalable units aligned to business capabilities, and a decade of experience literature has documented both the gains, autonomy, cadence, targeted scaling, and the pains, distributed complexity, operational burden, and data consistency across boundaries (Newman, 2015; Dragoni et al., 2017; Jamshidi et al., 2018; Soldani et al., 2018; Di Francesco et al., 2019; Zimmermann, 2017). The style's organizational logic is as old as the observation that system structure mirrors communication structure (Conway, 1968), and its operational logic is inseparable from the DevOps and continuous delivery practices that make many small deployables tractable (Balalaie et al., 2016; Bass et al., 2015; Humble & Farley, 2010; Forsgren et al., 2018), on the container and orchestration substrate that made service fleets an infrastructure commodity (Bernstein, 2014; Burns et al., 2016).

The communication question splits the style. Synchronous request-response between services reproduces, at network scale, the temporal coupling the decomposition sought to escape: caller availability becomes hostage to callee availability, latency compounds along call chains, and failures propagate synchronously. The event-driven alternative decouples in space, time, and synchronization through publish-subscribe distribution (Eugster et al., 2003), with the enterprise integration tradition supplying the message-flow patterns (Hohpe & Woolf, 2003) and

the microservice pattern literature codifying their service-scale forms, events as the integration fabric, sagas for workflows, event sourcing and query separation where they earn their cost (Richardson, 2018). The backbone technology matured in parallel: the partitioned, replicated log turned event distribution into durable, replayable, per-key-ordered infrastructure (Kreps et al., 2011; Wang et al., 2015; Ahmed & Odejobi, 2018), argued as the organizing abstraction for data-intensive architectures generally (Kleppmann & Kreps, 2015; Kleppmann, 2017), with stream processing ecosystems consuming it under exactly-once state semantics where derivation requires them (Carbone et al., 2017; Noghabi et al., 2017; Akidau et al., 2015) and comparative measurement locating its throughput-latency envelope among broker designs (Dobbelaere & Esmaili, 2017).

What the literatures leave to each team is the assembly. The patterns are individually documented and the platform primitives individually capable, yet the recurring adoption failures are compositional: topics that mirror tables instead of domain language, events published outside the transaction that changed state, consumers that assume delivery semantics the backbone never promised, workflows coordinated by ad hoc status polling, and operations teams discovering consumer lag as their first monitoring concept during an incident, the same class of late-discovered operational deficit that enterprise reliability and service-assurance research reports across large deployments (Oteri & Edivri, 2026). The distributed systems fundamentals that govern these compositions, ordering as a logical property (Lamport, 1978), the unavailability of cheap distributed transactions and the architectural response of local transactions plus reconciliation (Helland, 2007; Garcia-Molina & Salem, 1987), and the consistency-availability trade under partition (Gilbert & Lynch, 2002; Brewer, 2012), are settled; their translation into one coherent, stack-specific design is the gap. This paper proposes that translation as a blueprint: Spring Boot as the service chassis, Kafka as the backbone, and the decisions between them made explicitly. Section 2 reviews background; Section 3 states principles; Sections 4 through 8 specify the blueprint's layers; Section 9 sets out the evaluation plan; Sections 10 and 11 treat applications and limitations; Section 12 concludes.

2. Background and Related Work

The microservice literature frames the architectural problem and its evidence. Foundational treatments define the style's tenets and trade-offs (Newman, 2015; Zimmermann, 2017; Dragoni et al., 2017), systematic studies map research and practice (Di Francesco et al., 2019; Jamshidi et al., 2018), grey-literature synthesis catalogues practitioner-reported pains with data management and operational complexity prominent (Soldani et al., 2018), and migration studies document the pathways from monoliths that most adopters actually walk (Balalaie et al., 2016). Domain-driven design supplies the decomposition discipline the style presupposes, bounded contexts with explicit models and published languages between them (Evans, 2003), and the pattern catalogue assembles the event-driven repertoire at service scale, outbox, saga, event sourcing, query separation, with their forces and consequences (Richardson, 2018; Hohpe & Woolf, 2003), and integration-pattern studies in enterprise service-bus and multi-cloud settings show the same repertoire recurring well outside the microservice literature proper (Badmus et al., 2022).

The distributed data literature supplies the semantics the blueprint enforces. The log abstraction provides durable, partitioned, replayable event streams with per-partition order (Kreps et al., 2011; Wang et al., 2015; Kleppmann &

Kreps, 2015), consolidated treatments fix the delivery-semantics vocabulary, at-least-once transport hardened to effective exactly-once by idempotent processing, and the schema-evolution discipline long-lived event streams demand (Kleppmann, 2017), and the stream ecosystem demonstrates transactional, stateful consumption where derived views need it (Carbone et al., 2017; Noghabi et al., 2017; Akidau et al., 2015).

The coordination fundamentals bound what any blueprint may promise: sagas replace unavailable distributed transactions with sequences of local transactions and compensations (Garcia-Molina & Salem, 1987), the apostate position generalizes the pattern, scale-agnostic systems coordinate through local state plus asynchronous reconciliation (Helland, 2007), ordering claims reduce to logical structure (Lamport, 1978), and partition behavior forces the availability stance to be chosen, not discovered (Gilbert & Lynch, 2002; Brewer, 2012).

The operational literature supplies the plane the blueprint cannot omit. Containerized deployment and orchestration define the runtime substrate (Bernstein, 2014; Burns et al., 2016), with portable cloud-to-edge runtimes and their container comparisons marking that substrate's current frontier (Ojukwu et al., 2025), production stability patterns, timeouts, bulkheads, circuit breakers, backpressure, define boundary behavior under stress (Nygard, 2018), distributed tracing established request-scoped causality across service hops as an infrastructure service (Sigelman et al., 2010), with enterprise log analytics and automated incident response supplying the surrounding operational tooling (Mbonu et al., 2019), and delivery-performance research ties the whole to measurable organizational outcomes (Forsgren et al., 2018; Bass et al., 2015).

The blueprint's relationship to these literatures is assembly with commitment: it selects, per decision, one default with stated rationale and named exceptions, on the position that an opinionated coherent whole is worth more to adopters than a neutral catalogue, and it stakes that position on the evaluation plan of Section 9.

3. Design Principles

Six principles govern the blueprint. Domain first: services are bounded contexts, and events are the contexts' published language, so the event catalogue is a domain artifact reviewed like an API, not an implementation exhaust (Evans, 2003; Richardson, 2018). Facts, not commands, on the backbone: events record what happened, named in past-tense domain vocabulary, with commands confined to explicit request channels where a service genuinely instructs another, keeping the backbone an audit-grade history rather than a remote procedure bus (Hohpe & Woolf, 2003; Kleppmann, 2017). Declared semantics: every event class declares its ordering key, delivery class, retention, and compatibility policy, and consumers program against declarations, never against observed behavior (Kreps et al., 2011).

Local transactions plus asynchrony: no design element may require a distributed transaction; atomicity is local, coordination is event-driven, and workflows are sagas with specified compensation (Helland, 2007; Garcia-Molina & Salem, 1987). Idempotency everywhere: every consumer is idempotent by design, converting the backbone's at-least-once delivery into effective exactly-once processing without transport heroics (Kleppmann, 2017). Operable by construction: health semantics, tracing propagation, lag monitoring, and resilience patterns are chassis defaults in every service, not per-team retrofits (Nygard, 2018; Sigelman et al., 2010; Oteri & Edivri, 2026).

4. Blueprint Overview

The blueprint has four layers over the stack. The decomposition layer, Section 5, maps domains to services and events, producing the event catalogue that everything downstream implements. The backbone layer, Section 6, realizes the catalogue on Kafka: topic taxonomy, partitioning, schema registry discipline, and per-class delivery configuration. The consistency layer, Section 7, specifies how services change state and coordinate: transactional outbox publication, idempotent consumption, and saga orchestration, implemented as chassis components in Spring Boot so that correctness is inherited, not rebuilt. The operational plane, Section 8, packages deployment, observability, and resilience as the same chassis's defaults. The unit of adoption is the service template: a Spring Boot starter embodying the chassis, outbox publisher, idempotent consumer support, saga participation, health and tracing wiring, from which every service in the system is generated, which is how the blueprint's decisions become the system's invariants.

5. Decomposition and the Event Catalogue

Decomposition follows bounded contexts: each service owns one context's model and data, exposes commands and queries at its edge, and publishes domain events as its context's public language (Evans, 2003; Newman, 2015). The blueprint's discipline is that events are designed at the domain level before topics exist: each event names a business fact, carries the aggregate identity it concerns, the minimal state consumers need, and provenance metadata, event identifier, aggregate version, causation and correlation identifiers, and is documented in the catalogue with its ordering key, delivery class, and consumers. Two delivery classes suffice for most systems and are the blueprint's defaults: entity events, keyed current-state facts per aggregate where the latest supersedes, and action events, individually meaningful occurrences consumed at-least-once with idempotency, the same class distinction the log literature's compaction and retention machinery serves directly (Kleppmann, 2017; Kreps et al., 2011). Cross-context consumption is by translation: consumers map foreign events into their own model at an explicit anti-corruption boundary, preserving context autonomy against schema gravity (Evans, 2003; Richardson, 2018). The catalogue is versioned and reviewed as an interface artifact, because in this architecture it is one, and organizational alignment follows it in the direction the structural mirror predicts (Conway, 1968).

6. Backbone Design

Topics realize the catalogue one-to-one per event type within a naming taxonomy, context, entity or action, event name, with partitioning by aggregate identity so that per-aggregate order is structural (Kreps et al., 2011; Lamport, 1978); partition counts are capacity decisions made per topic from throughput and consumer parallelism targets, informed by the measured envelopes of the broker literature (Dobbelaere & Esmaili, 2017; Wang et al., 2015). Schemas are managed centrally with compatibility rules declared per topic, backward compatibility as the default so consumers upgrade independently, and evolution beyond it handled by explicit versioned successor topics with bridging, the discipline long-lived streams require (Kleppmann, 2017). Retention follows delivery class: entity topics compact to latest-per-key, action topics retain by time windows sized to replay and audit needs, and both choices are declared in the catalogue rather than discovered in broker configuration, with drift from those declarations treated as a monitored condition rather than an assumed constant. Producer and consumer

configurations are chassis-fixed per class, acknowledgment levels, idempotent production, read positions, and commit discipline, so that delivery semantics are system properties; deviations are catalogue-level exceptions with rationale, not per-team tuning. Stream-processing consumers, deriving views, joins, and windows from the backbone, run under the transactional state semantics the ecosystem provides where their outputs feed further events (Carbone et al., 2017; Noghabi et al., 2017; Akidau et al., 2015).

7. Consistency Layer

Atomic publication is solved once, by the transactional outbox: a service's state change and its outbound events commit in one local transaction, events written to an outbox table alongside the domain data, with a chassis relay publishing outbox rows to the backbone and marking them sent, at-least-once by construction and totally ordered per aggregate by the same transaction that ordered the state (Richardson, 2018; Helland, 2007). Idempotent consumption completes effective exactly-once processing: the chassis consumer records processed event identifiers within the consumer's local transaction, so redelivery is detected and discarded exactly where its effects would land, the composition the semantics literature prescribes over at-least-once transport (Kleppmann, 2017).

Workflows that span services are sagas with the blueprint's orchestration default: a saga orchestrator, itself an event-sourced state machine owned by the context that owns the business process, issues command events, consumes outcome events, and drives either completion or the specified compensation sequence, the local-transactions-plus-compensation structure the pattern's origin defines (Garcia-Molina & Salem, 1987; Richardson, 2018). Choreographed sagas, coordination emerging from services reacting to one another's events, remain a documented exception for short, two-party flows, with the trade named: orchestration concentrates process logic and visibility, choreography distributes both. Compensations are first-class catalogue events with the same delivery discipline, and saga state exposes process-level observability, where every in-flight workflow is, alongside the tracing of Section 8. Event sourcing as a service-internal persistence choice, and query-separated read models fed from the backbone, are supported options with stated adoption criteria, audit-critical aggregates and divergent read shapes respectively, rather than blueprint mandates, keeping the default persistence simple where the domain does not pay for more (Richardson, 2018; Kleppmann, 2017).

8. Operational Plane

Deployment packages every service as a container under orchestration, one service per deployable, configuration externalized, and the backbone operated as a platform service with its own capacity and upgrade discipline (Bernstein, 2014; Burns et al., 2016). Health is two-signaled from the chassis, liveness as process health, readiness as dependency health including backbone connectivity and schema availability, so orchestration decisions reflect the architecture's real dependencies. Observability is trace-centered and event-aware: correlation and causation identifiers propagate from edge requests through commands, events, and saga steps, so a business transaction is one trace across asynchronous hops, extending request-scoped tracing to the event fabric (Sigelman et al., 2010), and metrics center on the architecture's leading indicators, consumer lag per group and topic foremost, with outbox depth, saga age distributions, and dead-letter rates beside it, alarmed against declared budgets. Resilience applies the stability patterns at every boundary: timeouts and circuit breakers on synchronous edges, bounded retries with

backoff and dead-letter routing on consumption, bulkheaded consumer pools per topic class, and backpressure preferred to buffering wherever load exceeds capacity (Nygard, 2018). Failure drills are part of the plane's definition, broker partition, consumer stall, poison messages, saga compensation storms, because the blueprint's resilience claims are behaviors to be exercised, not properties to be believed, and the delivery practices that keep many services releasable, pipelines, progressive rollout, and rollback by redeploy, complete the operational contract (Humble & Farley, 2010; Balalaie et al., 2016; Forsgren et al., 2018).

9. Evaluation Plan

The blueprint is evaluated through a reference implementation of a representative multi-context domain, an order-fulfillment system with inventory, payment, and shipping contexts exercising entity events, action events, and a compensating saga. Phase one is conformance: property-based test suites drive the chassis components across crash points, relay failures, redeliveries, and concurrent consumers, asserting the consistency layer's guarantees, no lost or duplicated effects, per-aggregate order preserved, saga completion or full compensation, under systematic fault schedules, with the outbox, idempotency, and saga machinery each falsifiable in isolation before composition.

Phase two is resilience and capacity characterization: chaos experiments, broker node loss, network partition between services and backbone, poison-message injection, and consumer stalls, measure detection, containment, and recovery against the operational plane's declared behaviors (Nygard, 2018), and load characterization maps throughput and end-to-end latency, publish to consumed effect, across partition counts, payload sizes, and consumer parallelism, situating the blueprint's fixed configurations against the broker measurement literature's envelopes (Dobbelaere & Esmaili, 2017). Phase three is the developer-facing study: teams implement specified feature extensions against the reference system and against an unguided Spring-plus-Kafka baseline, comparing implementation effort, defect classes caught by the conformance suites, and time-to-correct-semantics, the blueprint's central claim, decisions made once, measured as reduced per-feature decision load and error rate. Acceptance is conjunctive: guarantees hold under fault schedules, operational behaviors match declarations under chaos, capacity envelopes suffice for the reference domain's targets, and the developer study shows the opinionation paying for itself.

10. Anticipated Applications and Migration

The blueprint targets the transactional domains where event-driven microservices earn their complexity: commerce and order management, logistics and fulfillment, booking and reservation systems, billing, and operational platforms whose processes span contexts and whose histories carry audit value (Richardson, 2018; Soldani et al., 2018). Its migration pathway is incremental by design: a monolith adopts the chassis at its edge, publishing entity events through an outbox added to its existing transactions, new capabilities are built as blueprint services consuming those events, and contexts are extracted along the catalogue's seams as ownership clarifies, the strangler-style progression the migration literature documents, here with the event fabric as the seam (Balalaie et al., 2016; Newman, 2015). Secondary applications follow from the artifacts: the chassis and conformance suites are reusable independently of full adoption, the catalogue discipline transfers to any event-driven estate regardless of

stack, and the reference implementation with its fault schedules constitutes a teaching and benchmarking vehicle for the semantics that teams most often learn during incidents.

11. Limitations

The blueprint's commitments bound its fit. Opinionation cuts against contexts it did not anticipate: extreme-throughput domains may outgrow the fixed configurations, latency-critical paths may justify synchronous edges the blueprint disfavors, and small systems may not repay the operational plane's weight, for which the honest guidance is that a modular monolith remains a respectable answer (Newman, 2015; Soldani et al., 2018). The consistency layer provides effective exactly-once processing and saga atomicity-by-compensation, not distributed transactions: business invariants spanning contexts must be designed as reconciliations, and domains that cannot tolerate compensation windows need different architecture, the constraint the fundamentals impose rather than the blueprint (Helland, 2007; Gilbert & Lynch, 2002). Stack specificity is deliberate and limiting: the design's concepts port, but its claims are demonstrated per implementation, and the evaluation's developer-study conclusions carry the usual external-validity bounds of such designs. Finally, the blueprint governs architecture, not modeling judgment: bounded contexts drawn wrongly propagate through catalogue, topics, and teams with the efficiency the whole design exists to provide, and no chassis compensates for a mis-modeled domain (Evans, 2003).

12. Conclusion

This paper has proposed an end-to-end blueprint for event-driven microservices on Spring Boot and Kafka: bounded-context decomposition with a reviewed event catalogue as the published language; a backbone design with aggregate-keyed partitioning, registry-governed schema evolution, and per-class delivery configuration fixed in a shared chassis; a consistency layer composing transactional outbox publication, idempotent consumption, and orchestrated sagas into effective exactly-once processing without distributed transactions; and an operational plane in which tracing across asynchronous hops, lag-centered monitoring, and exercised resilience patterns are inherited defaults. Its evaluation plan makes the assembly falsifiable: conformance under fault schedules, chaos against declared behaviors, measured capacity envelopes, and developer studies of the opinionation's value.

The position beneath the blueprint is that event-driven microservices fail in practice not for lack of patterns but for lack of assembly: the decisions are individually documented, collectively interdependent, and organizationally expensive to re-derive per team. Making them once, coherently, in an adoptable chassis converts a pattern catalogue into an architecture, and converts the semantics that teams currently learn from incidents into properties their systems have from the first deploy.

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The authors declare that they have no competing interests related to this work.

Consent for Publication

The authors declare that they approved this study for publication.

Authors' Contributions

All the authors contributed in the Conception and Design of the work, Data collection, Drafting the article, and Critical revision of the article.

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